

FIRST EUROPEAN HEC SOFTWARE WORKSHOP

25-26 October 2016

London, UK



US Army Corps
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Hydrologic Engineering Center



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Workshop: Build a Basic HEC-HMS Model from Scratch

This workshop is designed to help new users of HEC-HMS learn how to apply the software. Not all the capabilities in HEC-HMS are demonstrated in the workshop as the focus is on creating a working model and calibrating the model to an observed flood event. This workshop presents HEC-HMS model development, calibration, and uncertainty assessment. You will start with an existing HEC-HMS *Basin Model*, developed using HEC-GeoHMS. You will parameterize the *Basin Model*, create a *Meteorologic Model*, and simulate a historic event. You will calibrate the model to the historic event by manually adjusting model parameters to improve model performance. Then you will evaluate the effects of parameter uncertainty in computed flow by running an HEC-HMS *Uncertainty Analysis*.

Overview

In this workshop you will:

- Review developing a *Basin Model* with HEC-GeoHMS
- Review determining precipitation gage weights with HEC-GeoHMS
- Parameterize an HEC-HMS *Basin Model*
- Add streamflow and precipitation gage information to the project
- Create an HEC-HMS *Meteorologic Model*
- Create and compute an HEC-HMS *Simulation Run*
- Calibrate the model and evaluate model performance
- Create an uncertainty analysis and evaluate results

Background

The Punxsutawney Watershed (400 km^2) is part of the Allegheny River Basin located in western Pennsylvania, USA. Primary conveyance streams include: Stump Creek, East Branch Mahoning Creek, and Mahoning Creek. The confluence of Stump Creek and East Branch Mahoning Creek is located east of the enclave of Big Run. Mahoning Creek is downstream of the confluence. A map of the watershed is shown in Figure 1.

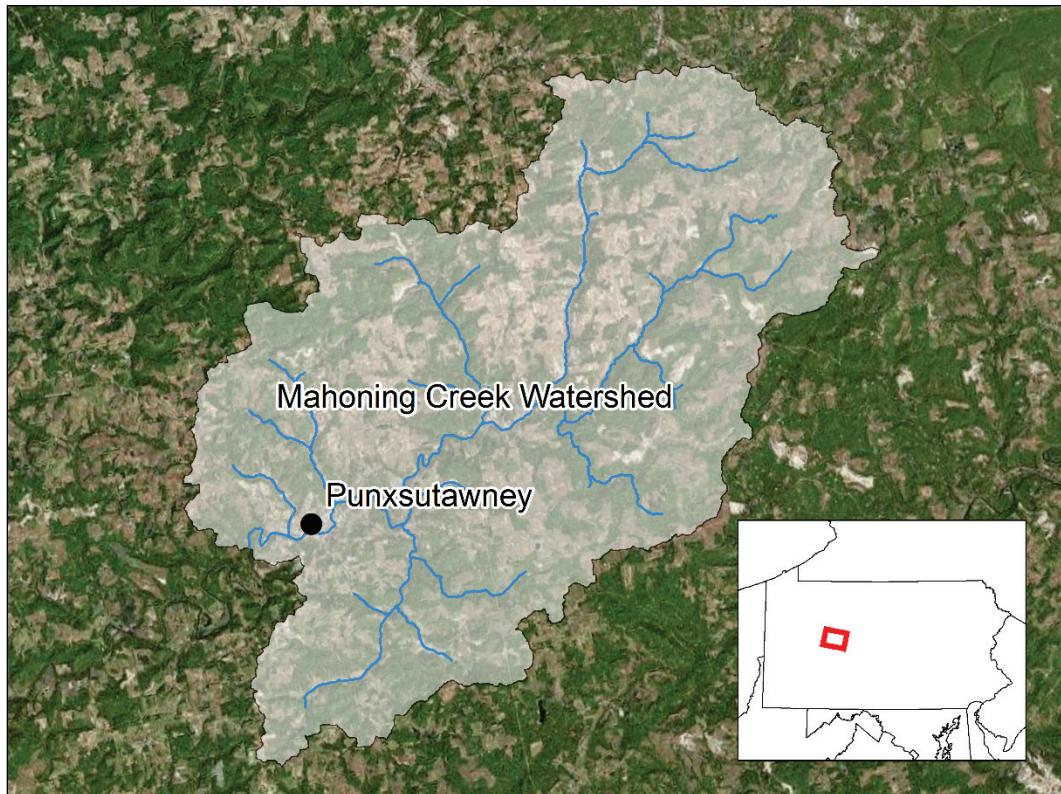


Figure 1. Study Area: Mahoning Creek upstream of Punxsutawney, PA

A storm event in April 1994 produced high-runoff in the town of Punxsutawney. Several regional precipitation gages and a discharge gage in Punxsutawney captured the event. These gages will be used to create a calibrated model of the event. The watershed will be modeled as 3 subbasins with incremental precipitation from recording rainfall gages; user-specified gage weighting will be used. Figure 2 shows the subdivided basin and nearby gages.

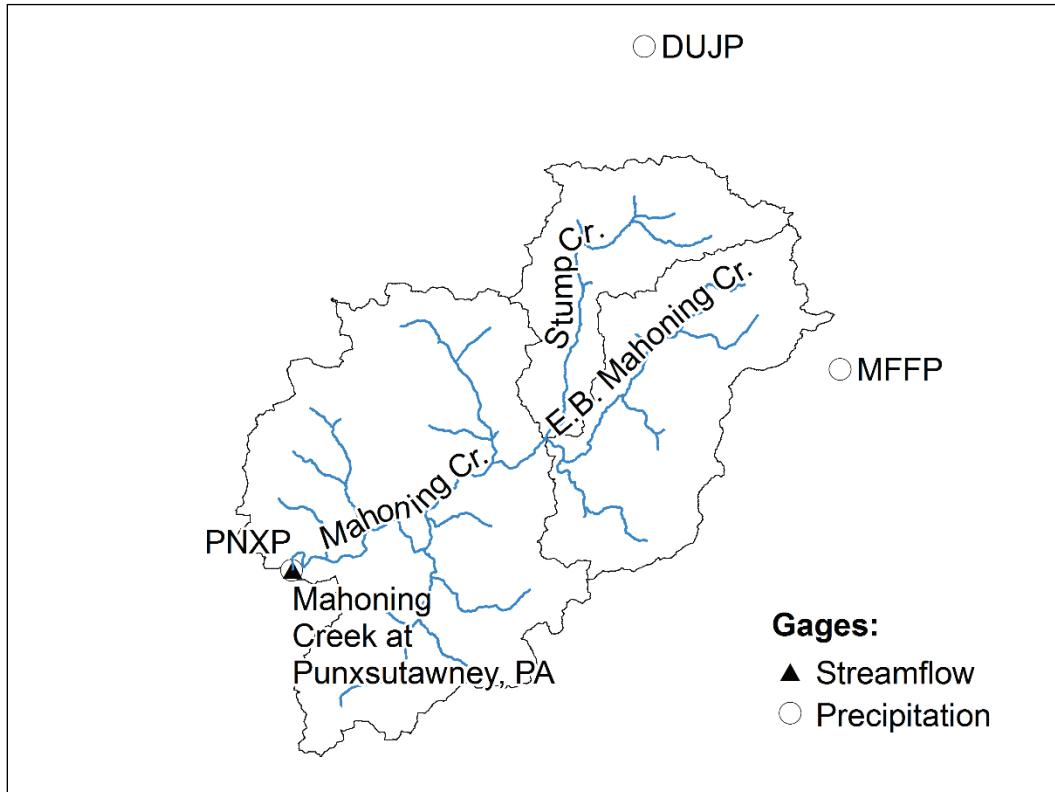


Figure 2. Precipitation and streamflow gages near Punxsutawney, PA

Tasks

1. Review: Develop a Basin Model with HEC-GeoHMS

Note: This task has been already been performed for you and is presented for your information.

Basin geometry is defined by delineating subbasins and river reaches. HEC-GeoHMS 10.2, an add-in to ArcGIS 10.2, was used to create the initial *Basin Model* using a 10 meter DEM of the watershed. The terrain grid was projected to UTM zone 17, and checked for missing data cells. Figure 3 shows the subbasin delineation in the HEC-GeoHMS project; notice the number of subbasins delineated. HEC-GeoHMS contains tools for merging and splitting subbasins and reaches to develop a stream and subbasin network that is appropriate given the type of study and calibration data available.

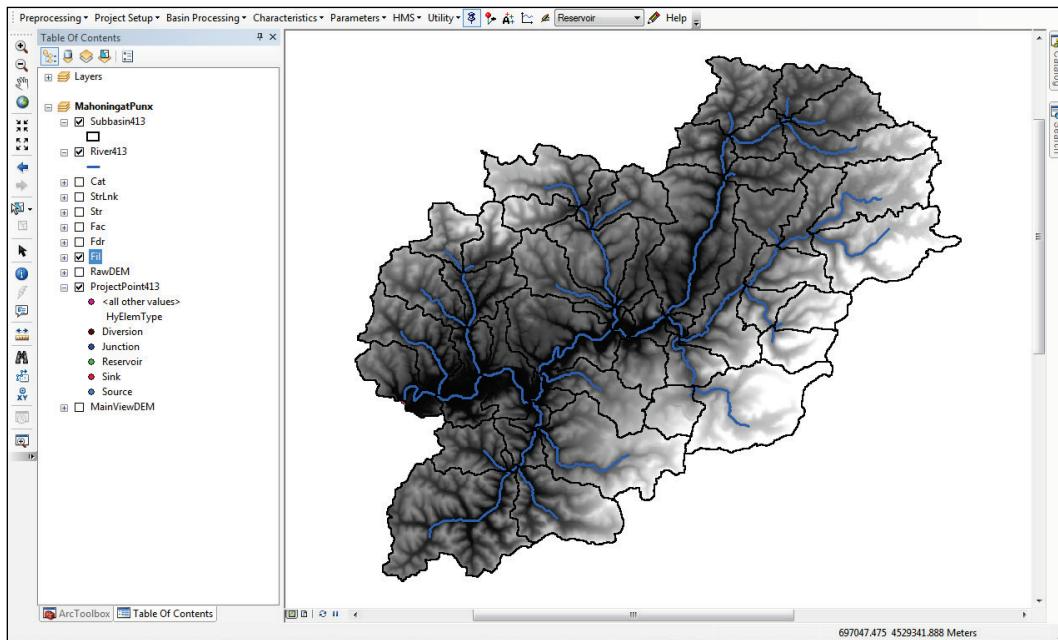


Figure 3. HEC-GeoHMS data frame in an ArcMap project

The watershed will be modelled with three subbasins; subbasins were merged as shown in Figure 4 and Figure 5.

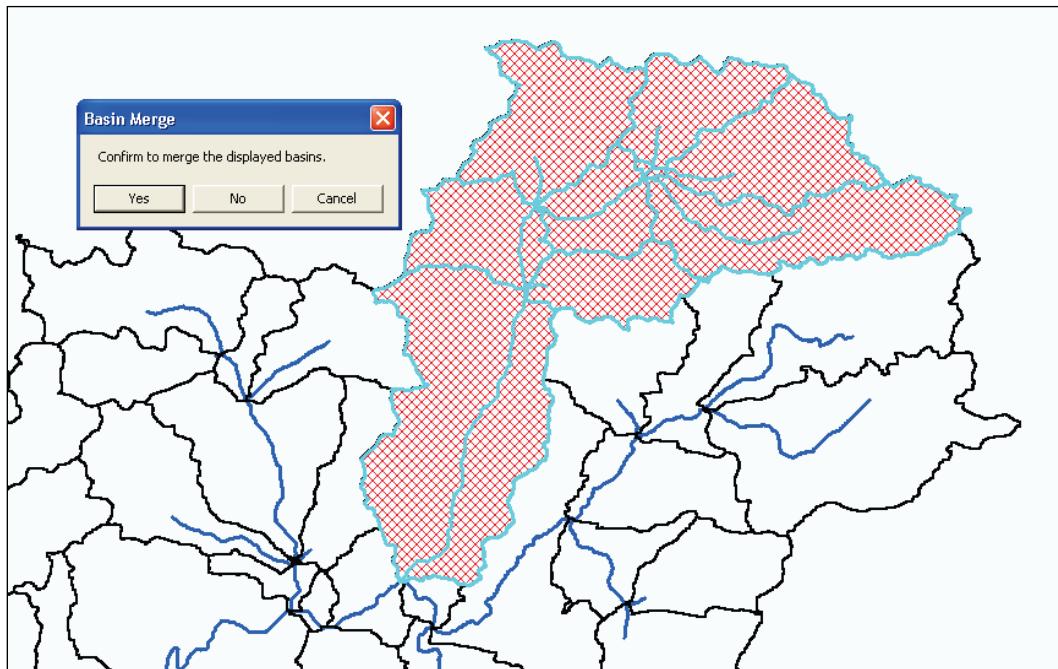


Figure 4. Merging subbasins in the Stump Creek Watershed

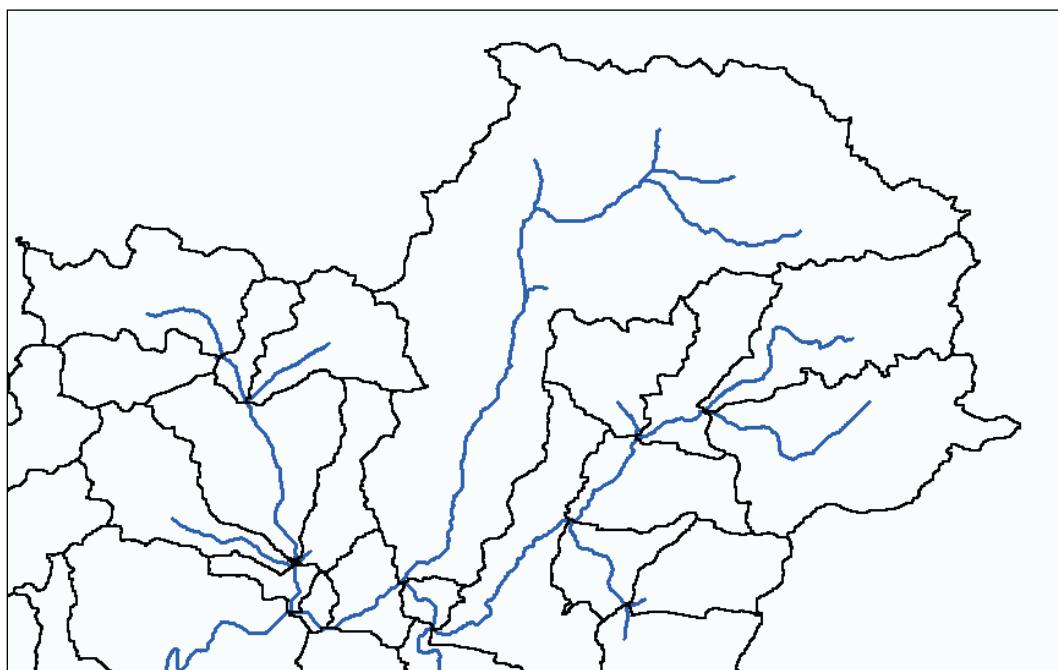


Figure 5. Stump Creek Watershed as 1 subbasin

The final subbasin delineation is shown in Figure 6.

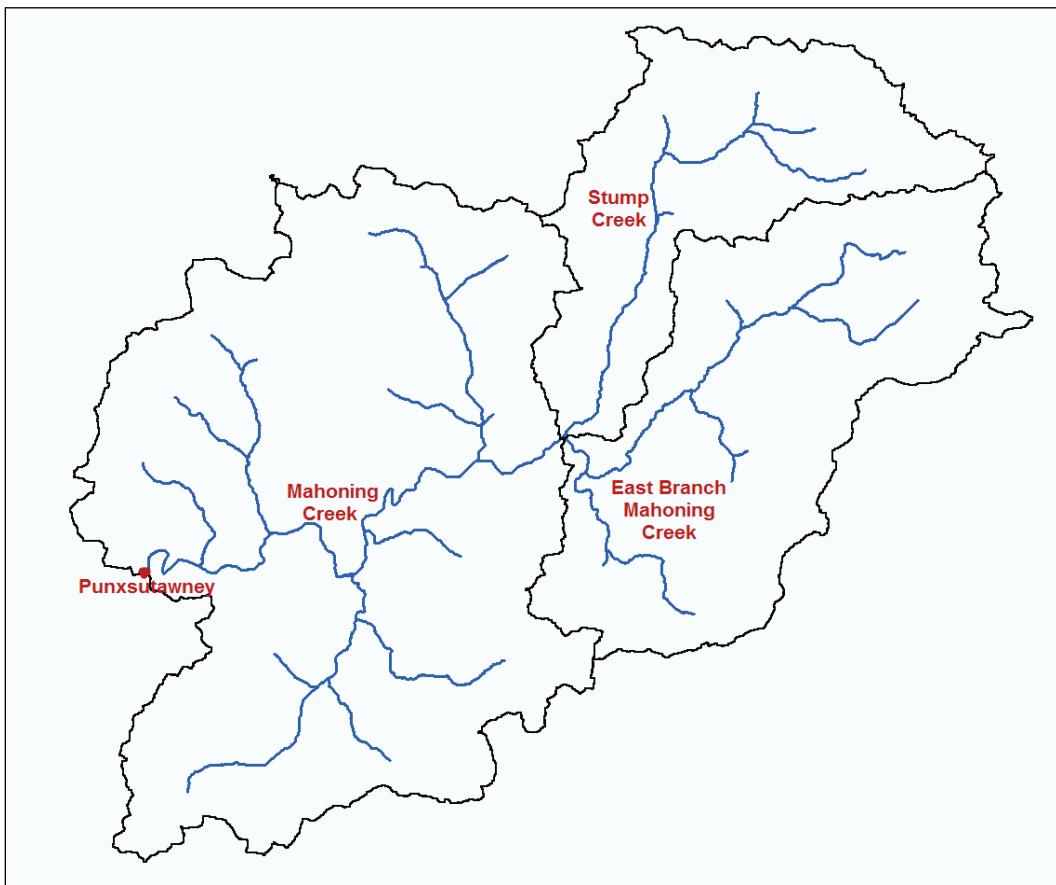


Figure 6. Final subbasin delineation of Mahoning Creek

2. ***Review: Determine Precipitation Gage Weights with HEC-GeoHMS***

Note: This task has been already been performed for you and is presented for your information.

HEC-GeoHMS was also used to estimate precipitation gage weights for computing basin average precipitation. Figure 7 shows three precipitation gages in the region and their location with respect to the watershed. HEC-GeoHMS contains tools for computing Thiessen polygons and computing the individual gage weights for each subbasin.

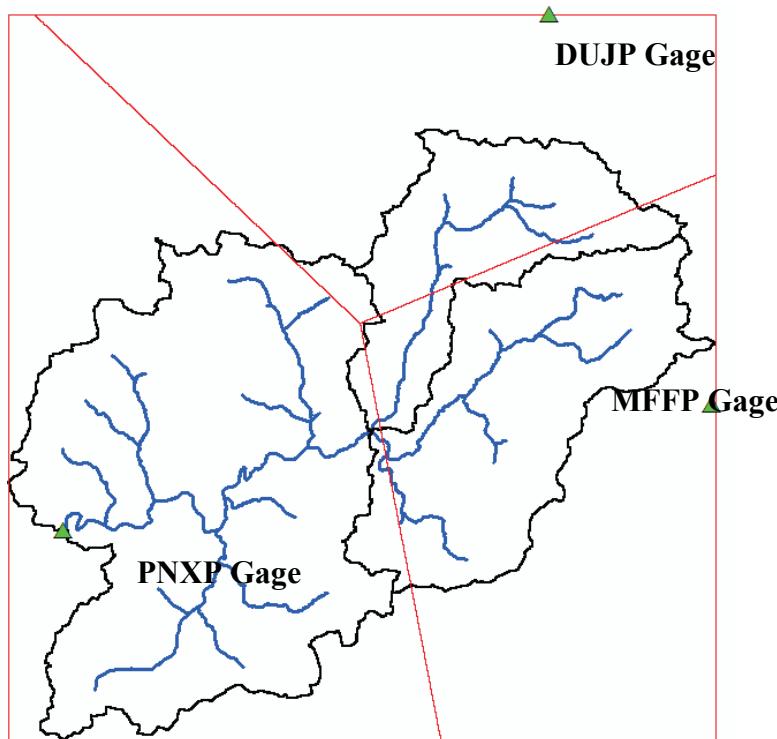


Figure 7. Thiessen polygons for Mahoning Creek gages

Results from the gage weight analysis in HEC-GeoHMS are shown in Table 1.

Table 1. Precipitation gage weights using Thiessen polygons

Subbasin	DUJP	MFFP	PNXP
E B Mahoning Creek	0.00	0.93	0.07
Mahoning Creek Local	0.02	0.00	0.98
Stump Creek	0.64	0.33	0.03

3. Parameterize the Basin Model

- 3.1. Double click the HEC-HMS icon  to start the program.
- 3.2. The main program window will appear; notice the menu bar across the top of the window with menus beginning with File and ending with Help. Also part of the window are the tool bars directly beneath the menu bar, the *Watershed Explorer*, the *Component Editor*, *Message Log*, and the *Desktop*. To open an existing project, click **File** and select **Open....**
- 3.3. The *Open an Existing Project* window will open; click **Browse** to open the **Select Project File** window. Navigate to the project directory and select the “**HMS_Example.hms**” file. Click the **Select** button and the existing project will open.
- 3.4. When the project opens, you will only see the *Basin Models* node - no other components have been added to the project. **Expand the Basin Models node and select the Basin Model “MahoniningatPunx”**. A map of the *Basin Model* should open as shown in Figure 8. Notice the subbasin area has been populated for each subbasin element, the elements have been connected hydrologically, and modeling methods have been selected – *Loss Method: Initial and Constant, Transform Method: Clark Unit Hydrograph, Baseflow Method: Recession, and Routing Method: Muskingum Routing*.

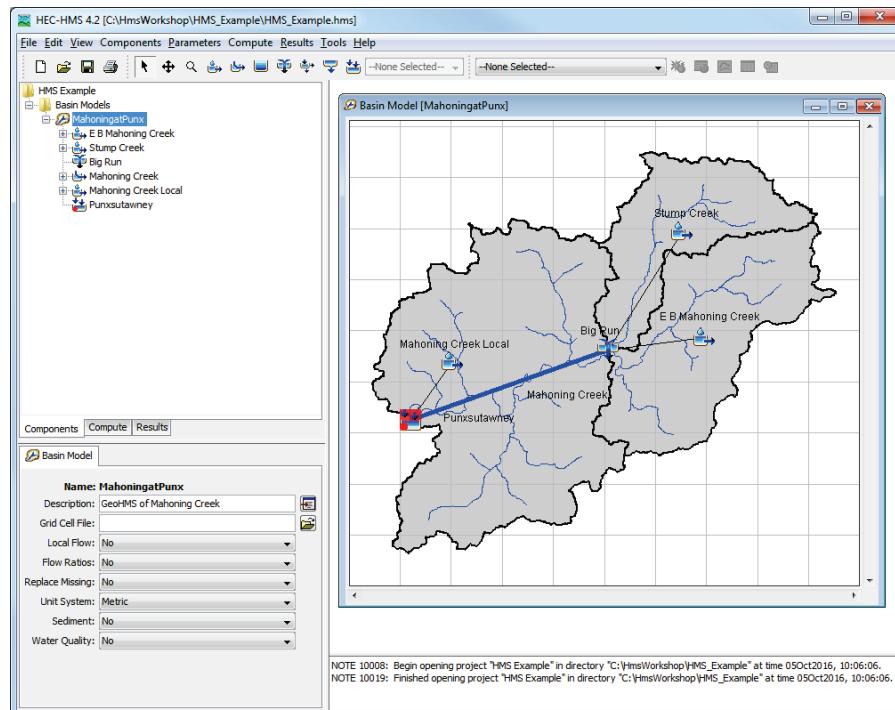


Figure 8. MahoningatPunx Basin Model map

- 3.5. The initial baseflow was determined by evaluating the observed baseflow at the beginning of the simulation and dividing by the total watershed area. The recession constant and ratio to peak values were determined from other regional models.

Enter baseflow parameters for each subbasin. From the Parameters menu select *Baseflow* \Rightarrow *Recession* to open the *Recession Baseflow* global editor. Set *Initial Type* to *Discharge Per Area*. Recession baseflow parameters are shown in Table 2.

Table 2. Recession baseflow parameters

Subbasin	Initial Q (m ³ /s/km ²)	Recession Constant	Ratio to Peak
E B Mahoning Creek	0.05	0.80	0.3
Stump Creek	0.05	0.80	0.3
Mahoning Creek Local	0.05	0.80	0.3

- 3.6. A table relating the Hydrologic Soil Group and landuse type to the constant loss rate was used to estimate the constant loss rate for each of the subbasins. The dominant soil types are Soil Group B and C and the dominant landuse in the watershed is Pasture/Dryland and Woodland/Grass. The initial loss was estimated based on the number of dry days prior to the storm event. The impervious area parameter was estimated based on GIS datasets.

Enter initial and constant loss parameters for each subbasin. From the Parameters menu select *Loss* \Rightarrow *Initial Constant Loss* to open the *Initial Constant Loss* global editor. Initial and constant loss rate parameters are shown in Table 3.

Table 3. Initial and constant loss rate parameters

Subbasin	Initial Loss (mm)	Constant Loss Rate (mm/hr)	Impervious Area (%)
E B Mahoning Creek	8	2.5	3.0
Stump Creek	8	3	3.0
Mahoning Creek Local	8	2.8	5.0

- 3.7. The time of concentration was estimated using the TR-55 method where the travel time along the longest flowpath was estimated using slope, land use characteristics, and channel geometry. The

storage coefficient was estimated using regional regression information between the time of concentration and the storage coefficient. The simple relationship is storage coefficient = 1.6 X time of concentration.

Enter Clark unit hydrograph parameters for each subbasin. From the *Parameters* menu select *Transform* \Rightarrow *Clark Unit Hydrograph* to open the *Clark Transform* global editor. Clark transform parameters are shown in Table 4.

Table 4. Clark unit hydrograph parameters

Subbasin	Time of Concentration (hr)	Storage Coefficient (hr)
E B Mahoning Creek	3.7	5.9
Stump Creek	5.3	8.5
Mahoning Creek Local	6.0	9.6

- 3.8. The routing reach, Mahoning Creek, is used to route flow from the Big Run junction to the Punxsutawney junction. The Muskingum routing method was selected for this workshop. The Muskingum K was estimated by computing a typical velocity for bank full flow and then using the reach length. The Muskingum K was determined to be **4 hours**. The *Muskingum X* and number of *Subreaches* are parameters best determined during model calibration. Set the *Muskingum X* to **0.25** and number of *Subreaches* to **4**.

In the *Basin Map*, select the reach element “Mahoning Creek.” The element is now editable in the *Component Editor*. Select the *Routing* tab. Enter a *Muskingum K* of 4 hours, a *Muskingum X* of 0.25, and number of *Subreaches* of 4.

You have now completed the basin model for this project. The next step is to add observed flow and precipitation gage information.

4. Add Streamflow and Precipitation Gage Information

- 4.1. Create a new precipitation gage. **From the *Components* menu select *Time-Series Data Manager*.** In the manager window, **press the *New...* button** to create a gage; the window for creating a gage will open.
- 4.2. In the new gage window, **change the default name to DUJP.** **Press the *Create* button** to create the new gage; it will automatically be added to the watershed explorer. You can leave the manager window open since it will be used again shortly.

- 4.3. In the **Watershed Explorer**, browse to the gage you just created. In the **Component Editor** set **Data Source** to **Single Record HEC-DSS**.
- 4.4. Select the correct external data source. You can click on the select  button next to the filename field to navigate to the file. Browse to ...\\HMS_Example\\data\\observe.dss. It is good practice to store all external DSS data within the project directory. That way, the information is contained in the project and will be included whenever the model is handed off to others for application or review.
- 4.5. Select the correct pathname. You can use the **Search by Parts** filters near the top of the screen to find pathnames. **Select the pathname with B-Part “DUJP” and C-Part “PRECIP-INC”** (Figure 9). **Click Set Pathname**.

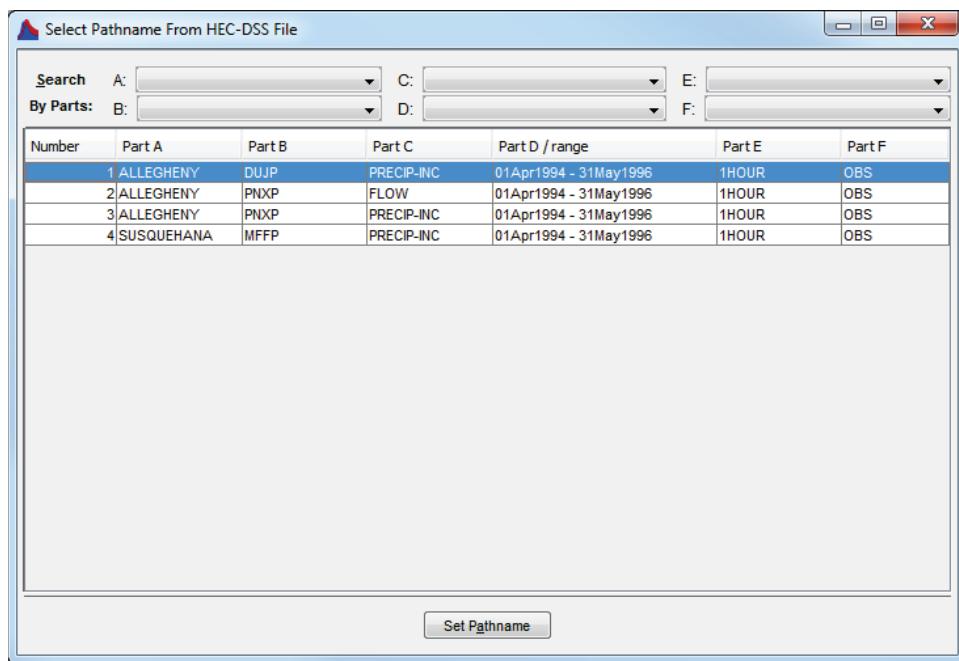


Figure 9. Selecting a the "DUJP" precipitation record

- 4.6. Change the default time window to inspect some of the data. In the **Watershed Explorer**, click on the time window under the “DUJP” gage icon. In the **Component Editor**, change start date to 10Apr1994, the start time to 00:00, the end date to 15Apr1994, and the end time to 00:00. Click on the **Table** and **Graph** tabs in the **Component Editor** to see the data, as shown in Figure 10.

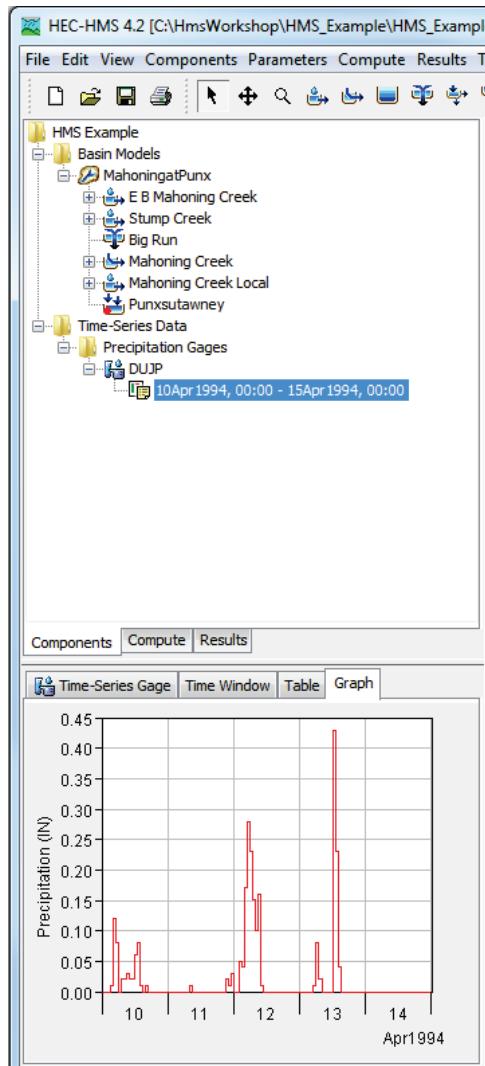


Figure 10. Viewing data in the component editor

You have finished setting up the “DUJP” time-series precipitation gage. We will use the gage later by referring to it by name.

Repeat steps 4.1 to 4.6 to create the “PNXP” and “MFFP” precipitation gages.

All of the precipitation data is now ready to use.

- 4.7. Add observed flow gage data. In the **Time-Series Data Manager**, change the data type to **Discharge Gage** and add a new gage. Name the gage Punxsutawney Observed Flow and link it to the flow record at Punxsutawney in the observe.dss file (B-Part = PNPX, C-Part=FLOW). Change the time window for the discharge gage and view the flood hydrograph for the April 1994 event, as shown in Figure 11.

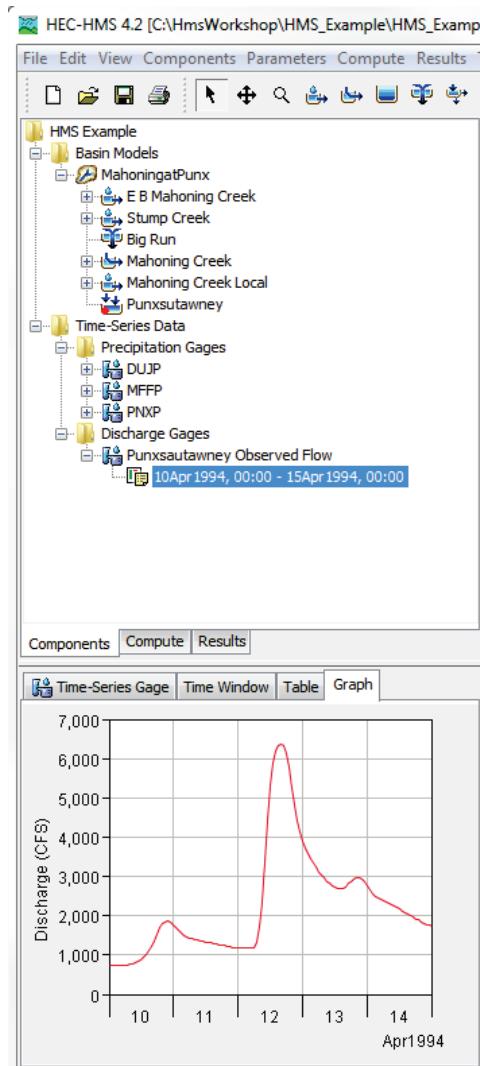


Figure 11. Flood hydrograph for April 1994 event

- 4.8. Reference the observed flow gage in the basin model to compare compute and observed results for the April 1994 simulation. **In the Basin Model map, click on the junction element “Punxsutawney” to open the Component Editor.** Select the Options tab, click the dropdown for **Observed Flow**, and select **“Punxsutawney Observed Flow.”**

5. **Create a Meteorologic Model**

- 5.1. **From the Components menu select the Meteorologic Model Manager; the Meteorologic Model Manager will open.** Press the **New...** button to create a new meteorologic model.
- 5.2. **Change the default name to GageWeights and press the Create button to create the new meteorologic model.**
- 5.3. In the *Watershed Explorer*, browse to the new meteorologic model. **Click on the model “GageWeights”.** In the **Component Editor**, set the **Precipitation method to Gage Weights**. The evapotranspiration and snowmelt methods should be turned off, the unit system should be set to metric, and the **Replace Missing option should be Set to Default**.
- 5.4. Connect the meteorologic model to subbasins in the basin model. **In the Component Editor, open the Basins tab. For basin model “MahoningatPunx,” set Include Subbasins to Yes.**

The Gage Weights precipitation method requires parameters for each subbasin element in the basin model. The gage weights presented in Table 1 will be used in the Meteorologic Model for computing the total subbasin average precipitation. Only one gage will be used to define the time pattern.

- 5.5. In the *Meteorologic Model*, expand the node for “E B Mahoning Creek.” A *Gage Weights* node will display (Figure 12).

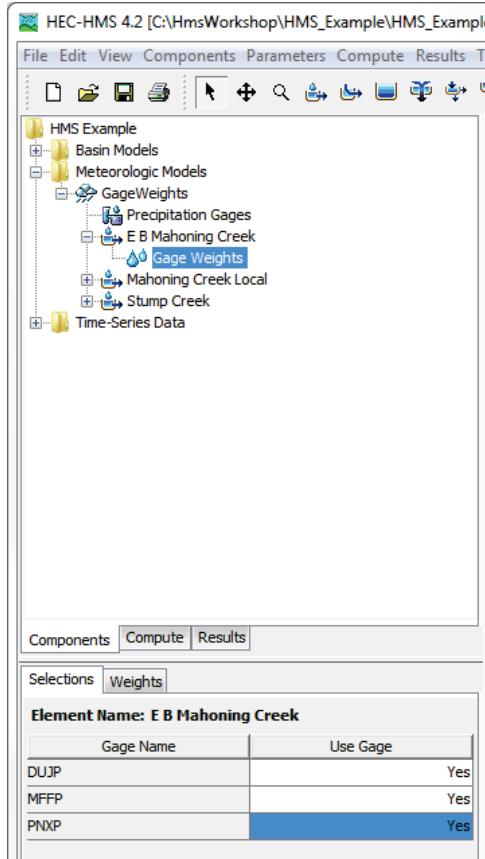


Figure 12. Gage Weights node selected

- 5.6. Select the *Gage Weights* node. The *Component Editor* will have two tabs: **Selections** and **Weights**. On the **Selections** tab, for each gage “DUJP,” “MFFP,” and “PNXP” change the *Use Gage* option to Yes.
- 5.7. Select the **Weights** tab. Enter the Depth Weight for each precipitation gage calculated using Thiessen polygons, shown in Table 1. The depth weight can be entered as either percentage in decimal format (Figure 13) or as an area.

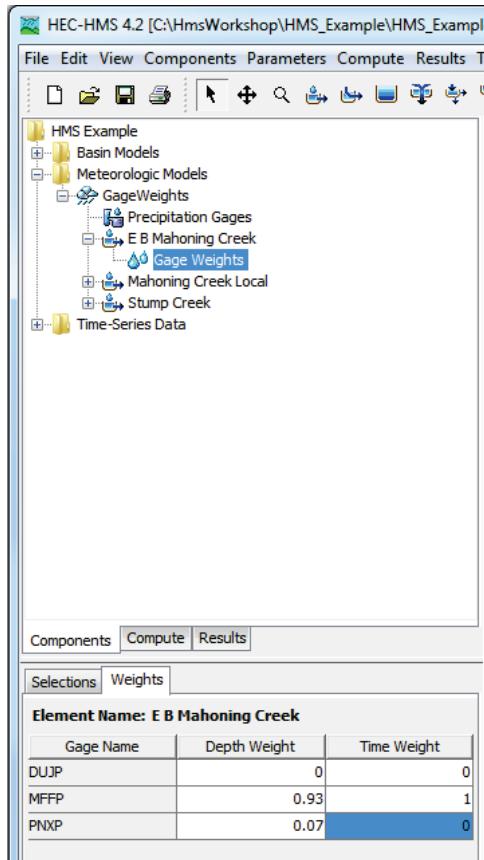


Figure 13. Depth and time weights specified for the E B Mahoning Creek subbasin

- 5.8. For subbasin “E B Mahoning Creek,” enter a Time Weight of 1 . 0 for the “MFFP” gage and 0 . 0 for the “PNXP” and “MFFP” gages. Here, the temporal distribution of the resulting hyetograph is solely governed by the temporal precipitation distribution of the “MFFP” gage.

Repeat steps 5.5-5.8 for subbasins “Mahoning Creek Local” and “Stump Creek.” For “Mahoning Creek Local,” set the Time Weight to 1 for the “PNXP” gage and to 0 . 0 for the “MFFP” and “DUJP” gages. For “Stump Creek,” set the Time Weight to 1 for the “DUJP” gage and 0 . 0 for the “PNXP” and “MFFP” gages.

You have now completed the User-Specified Gage Weights Meteorologic Model.

6. Create and run a simulation

In order to create a Simulation Run, a Basin Model, a Meteorologic Model, and Control Specifications need to be defined in the project.

- 6.1. Create a new **Control Specifications**. From the **Components** menu select **Control Specifications Manager**; the manager window will open. Press the **New...** button to create a new control specifications.
- 6.2. **Change the default name to 1994 Event.** Press the **Create** button to create the new **Control Specifications**.
- 6.3. In the *Watershed Explorer*, browse to the new **Control Specifications**. Enter start date and time as **10Apr1994 at 00:00**. Enter end date and time as **15Apr1994 at 00:00**. Select **1 Hour** for the time interval, as shown in Figure 14.

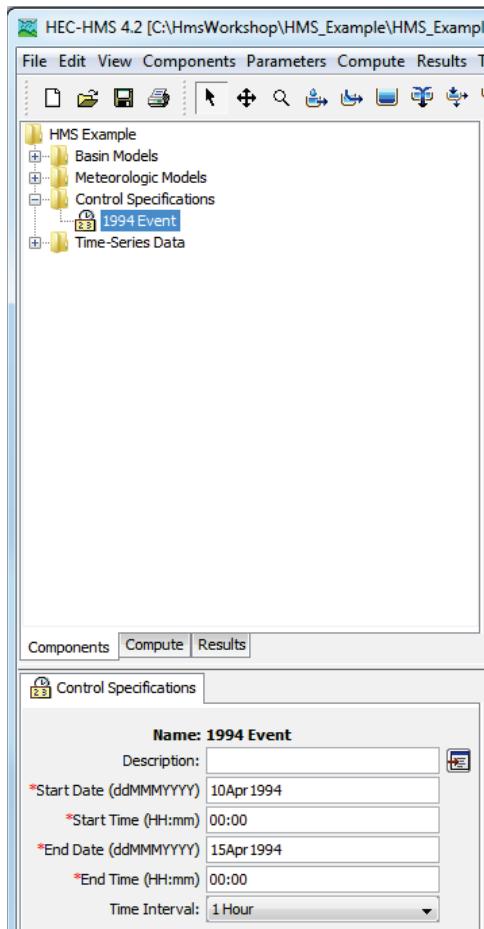


Figure 14. Control Specifications entered

The Basin Model, Meteorologic Model, and Control Specifications are complete. Now you will create and compute a Simulation Run.

- 6.4. From the **Compute** menu, select **Create Compute ⇒ Simulation Run**. A wizard window will open for creating a new simulation run. In Step 1, enter **Simulation Run name**: Run 1994 Flood Event. In Step 2, choose the “**MahoningatPunx**” Basin Model. In Step 3, choose the “**GageWeights**” Meteorologic Model. In Step 4, choose the “**1994 Event**” Control Specifications. Press the **Finish** button to complete the process of creating a **Simulation Run**.
- 6.5. Compute the **Simulation Run**. A **Simulation Run** must be selected before it can be computed. The **Compute** tool bar includes a selection list that shows all of the simulation runs that have been created in the project. Click on the selection list and choose “**Run: Run 1994 Flood Event**.” Once a **Simulation Run** has been selected, click the **Compute** button  immediately to the right of the selection list to perform the compute, as shown in Figure 15. The **Compute** button is available on the tool bar when a **Simulation Run** is selected. Alternately, from the **Compute** menu select the **Compute Run** (the name of the selected run will be shown within brackets next to the **Compute Run** menu option).

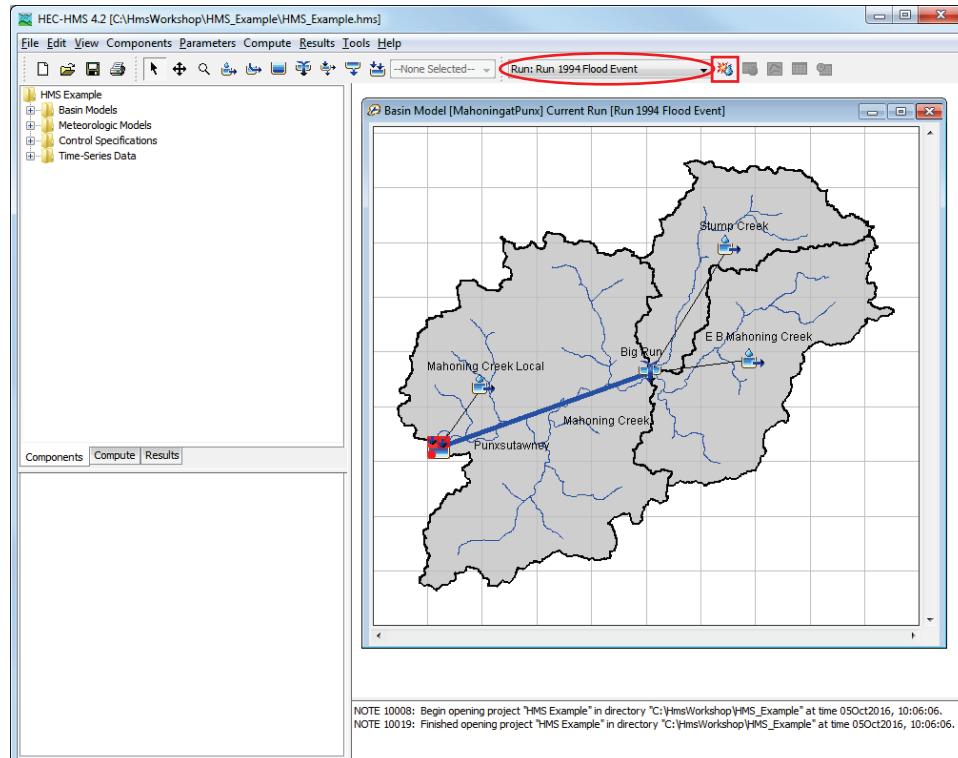


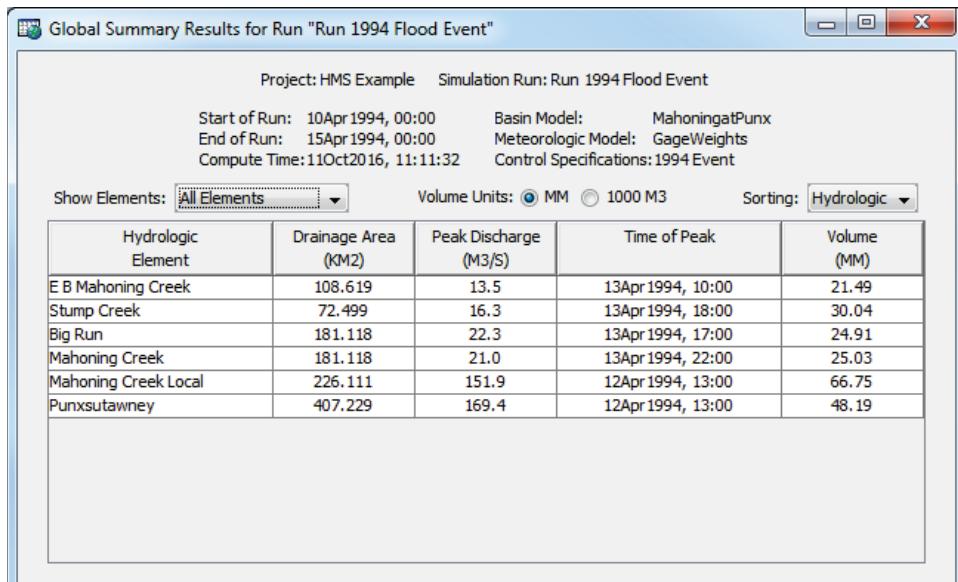
Figure 15. Select simulation and compute from the HEC-HMS tool bar

- 6.6. A *Compute Progress* window will open to show the advancement of the simulation. The simulation may abort if errors are encountered. If this happens, read the messages and fix any problems; then compute the *Simulation Run* again. **Close the progress window when the run computes successfully.**

Results are now available from the completed Simulation Run.

- 6.7. From the **Results** menu select the **Global Summary Table**. This *Global Summary Table* will display as shown in Figure 16.

Alternately you can click the *Global Summary Table* button  on the *Compute* tool bar.



The screenshot shows the "Global Summary Results for Run 'Run 1994 Flood Event'" window. At the top, it displays project details: Project: HMS Example, Simulation Run: Run 1994 Flood Event. Below that are run parameters: Start of Run: 10Apr1994, 00:00; End of Run: 15Apr1994, 00:00; Compute Time: 11Oct2016, 11:11:32. It also shows basin model information: Basin Model: MahoningatPunxsutawney, Meteorologic Model: GageWeights, and Control Specifications: 1994 Event. The main area contains a table with the following data:

Hydrologic Element	Drainage Area (KM ²)	Peak Discharge (M ³ /S)	Time of Peak	Volume (MM)
E B Mahoning Creek	108.619	13.5	13Apr1994, 10:00	21.49
Stump Creek	72.499	16.3	13Apr1994, 18:00	30.04
Big Run	181.118	22.3	13Apr1994, 17:00	24.91
Mahoning Creek	181.118	21.0	13Apr1994, 22:00	25.03
Mahoning Creek Local	226.111	151.9	12Apr1994, 13:00	66.75
Punxsutawney	407.229	169.4	12Apr1994, 13:00	48.19

Figure 16. Global summary results for Run 1994 Flood Event simulation

- 6.8. View results for each *Basin Model* element. Right-click on an element in the *Basin Map*; a context menu is displayed with several choices including *View Results*. From the *View Results* menu there are options to view graph, summary table or time-series table. The same results are available from the *Results* tab of the *Watershed Explorer*.

- 6.9. View the observed vs. computed hydrograph by selecting the *Graph* option for the junction “*Punxsutawney*” (Figure 17). The computed hydrograph shape is similar to the observed hydrograph shape; however, the peak flow and runoff volume are low and the timing of the peak flows do not coincide. At this point, model parameters have only been estimated using GIS datasets and regional information. The model must be calibrated for computed results to approximate observed flow.

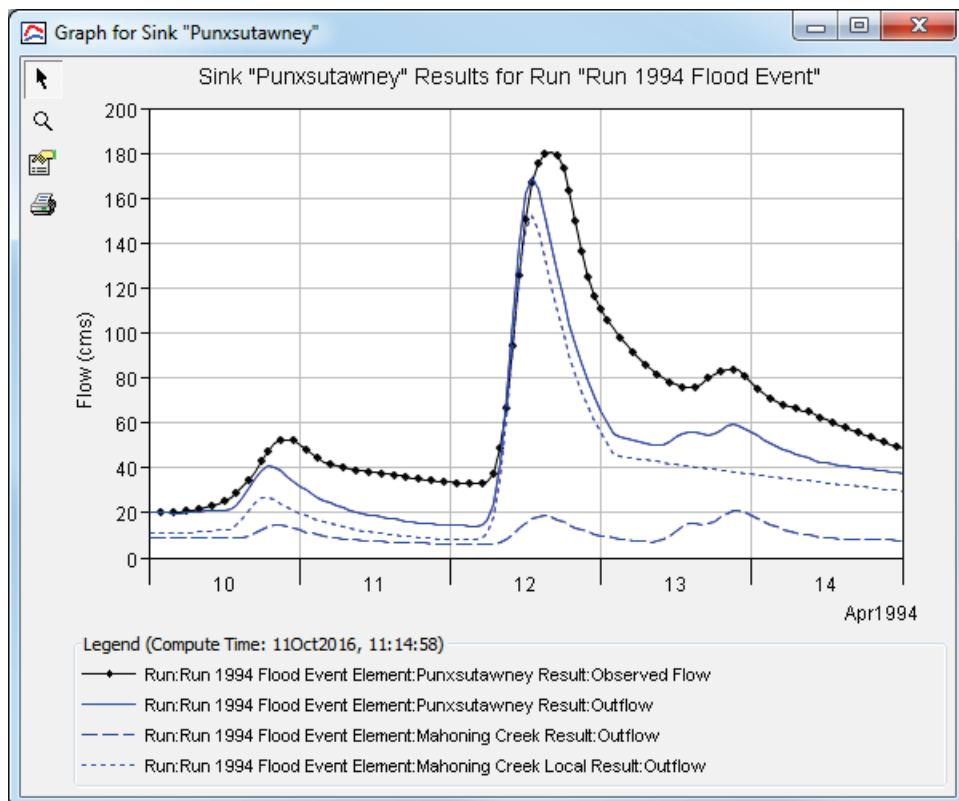


Figure 17. Observed vs. computed hydrograph at the Punxsutawney junction

7. Calibrate the model and evaluate model performance

Initial parameter values will be refined through several calibration runs.

- 7.1. First, loss parameters can be adjusted to increase the runoff volume. The summary results for the junction “*Punxsutawney*” show the observed runoff volume is 68.42 mm and the computed runoff volume is 48.19 mm. Decreasing the initial loss rate might improve the results on April 10 and 11. **Select the Parameters⇒Loss⇒Initial and Constant Loss menu option to open the Initial and Constant Loss global parameter table. Reduce the Initial Loss and re-run the simulation.** You will notice the computed flow hydrograph is not sensitive to the initial loss rate, even when setting the initial loss to 0 mm. This is likely due to the precipitation intensity and the constant loss rate values.
- 7.2. In addition to *Initial Loss* reduce the *Constant Loss Rate* to increase the computed runoff volume and increase the computed peak flows. The *Initial Constant Loss* global parameter table contains special editors to adjust all selected cells. **Highlight all three Constant Rate values, right click and choose Fill.... In the Table Fill Options editor, choose the Multiply by constant: option and enter 0 . 75, as shown in Figure 18. Re-compute the simulation.**

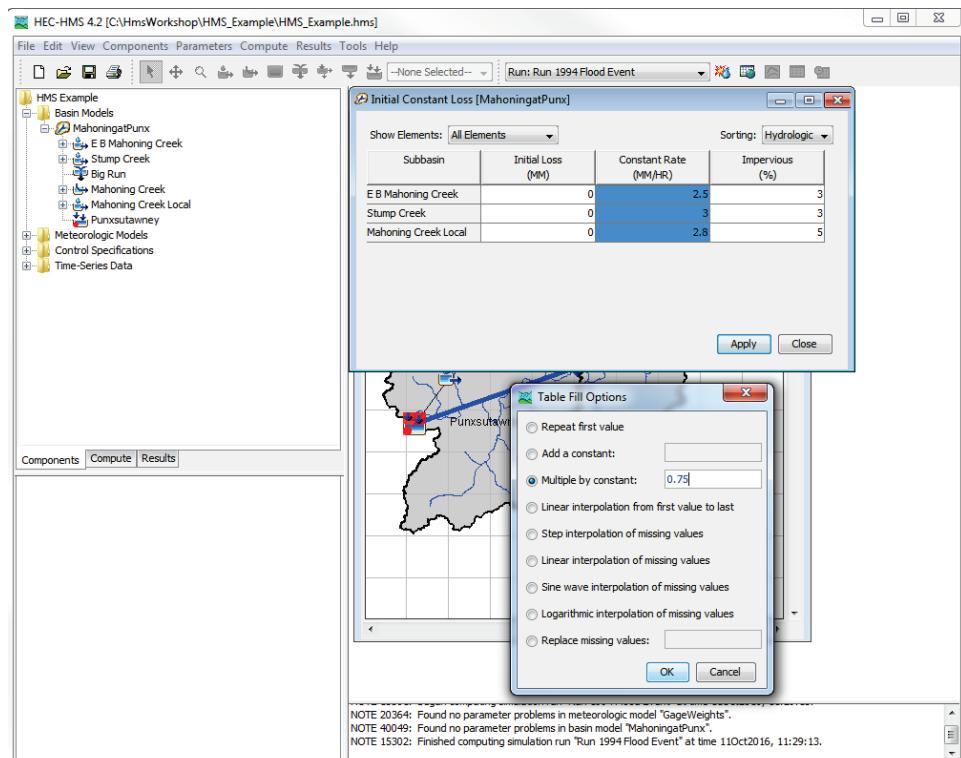


Figure 18. Editing initial and constant loss rate values

Notice the computed peak flow exceeds the observed, but the timing of the computed peak flow is early when compared to the observed hydrograph, as shown in Figure 19.

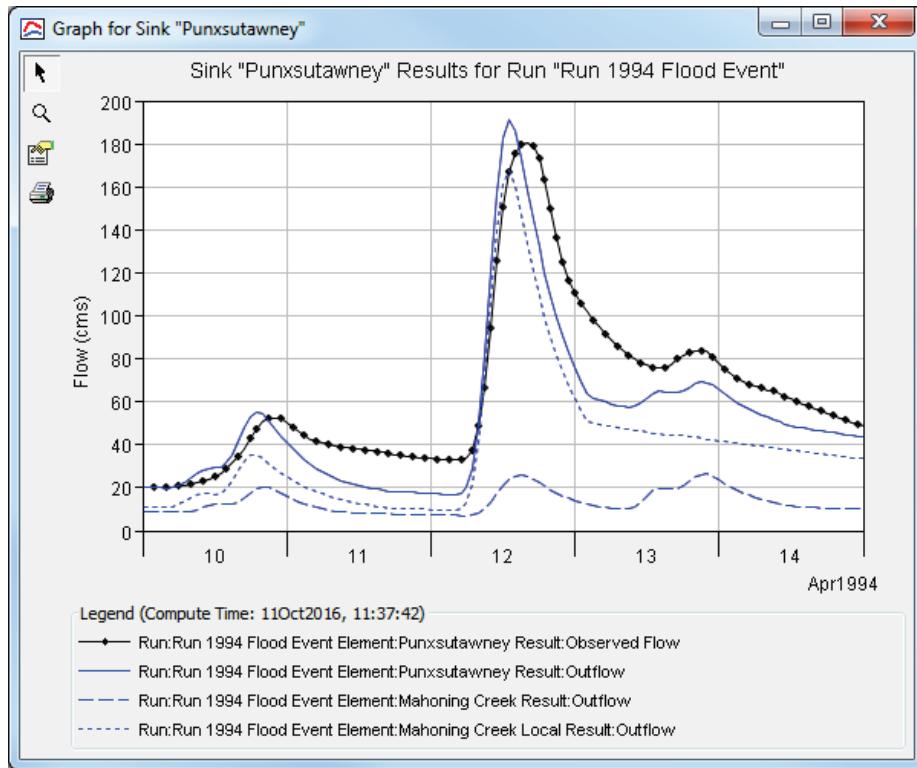


Figure 19. Comparison of simulated and observed hydrographs after editing initial and constant loss rates

- 7.3. The Clark unit hydrograph parameters control the timing and attenuation of runoff from subbasin elements. Notice in Figure 19 that a majority of the runoff at the junction “*Punxsutawney*” is due to runoff from the subbasin “*Mahoning Creek Local*” (the plot at this junction shows all upstream contributions plus the total inflow). Before adjusting the UH parameters for the subbasins “*Stump Creek*” and “*E B Mahoning Creek*,” adjust the Clark unit hydrograph parameters for the subbasin “*Mahoning Creek Local*” only. **Select this subbasin in the Basin Map to open the Component Editor. Go to the Transform tab and change the Time of Concentration from 6 hours to 9 hours and the Storage Coefficient from 9.6 to 14.4 hours (maintaining the relationship $R = 1.6 * Tc$). Recompute the simulation and compare results at the junction “*Punxsutawney*.”**

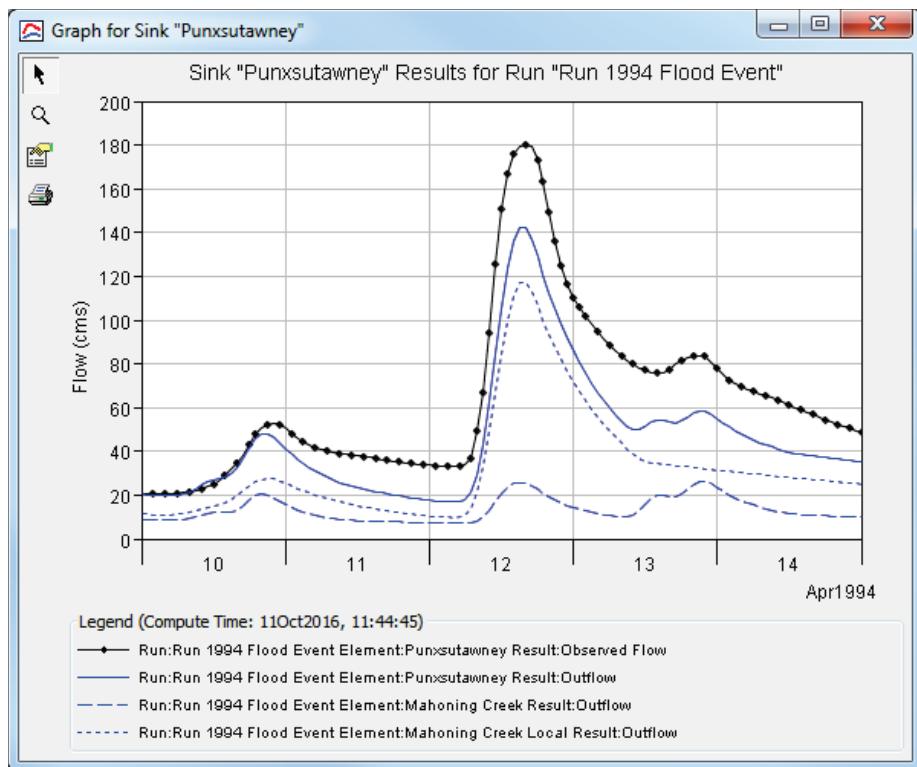


Figure 20. Comparison of simulated and observed hydrographs after editing the Clark unit hydrograph parameters for the subbasin “Mahoning Creek Local”

- 7.4. As shown in Figure 20, the timing of the runoff hydrograph is greatly improved, however, the peak flow and volume need some additional adjustment. **Within the *Initial Constant Loss Global Parameter Table*, reduce the constant loss parameters by multiplying values by 0.4 and set the initial loss to 6 mm for all subbasins. Re-compute the simulation and compare results at the junction “Punxsutawney.”**

7.3 Figure 21 shows the computed results and observed flow after the above changes were made to the model. The computed volume, 62.31 mm, is much closer to the observed volume, 68.42 mm, and the timing and magnitude of the peak flow is much closer as well. The Nash-Sutcliffe metric is 0.949 for this simulation. The summary table for the junction “Punxsutawney” is shown in Figure 22.

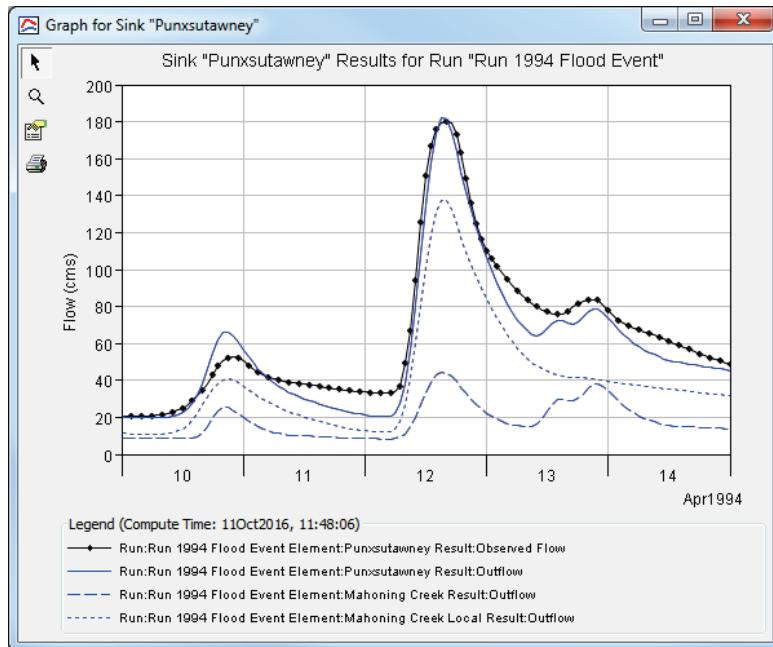


Figure 21. Comparison of simulated and observed hydrographs after editing the initial and constant loss parameters a second time

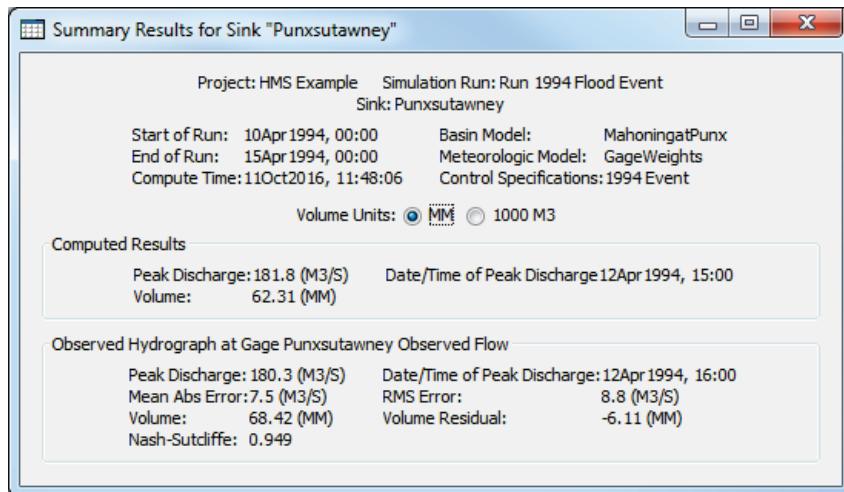


Figure 22. Summary table after model calibration is complete

The final loss and transform parameter values are presented in Table 5 and Table 6. Slight adjustments were required from the initial parameter estimates. Additional modification could be made to the recession

*baseflow parameters to improve the model fit to the baseflow portion of the runoff hydrograph. For example, increasing the **Recession Constant** to 0.9 increases the computed runoff volume to 65.68 mm and increases the Nash-Sutcliffe metric to 0.971. The model should be calibrated to additional flood events and then a final set of parameter values determined. Additionally the model should be validated against multiple flood events.*

One thing to note is that boundary condition information should be evaluated when attempting to calibrate a model. The loss rates required for the April 1994 event that resulted in the best fit of modeled results are extremely low. Comparison of precipitation gage information from the DUJP, PNXP, and MFFP gages showed 64.77 mm, 83.82 mm, and 27.43 mm, respectively. This variability in measured precipitation shows the precipitation was not homogeneously distributed over the gages and watershed. It's likely that the low constant loss rates are due to inadequately modeling precipitation over the entire watershed. The meteorologic model could be updated and more depth weight applied to the PNXP precipitation gage. Applying a larger depth weight would result in higher basin average precipitation, which would result in loss rates that are more reasonable.

Table 5. Final initial and constant loss rate parameters

Subbasin	Initial Loss (mm)	Constant Loss Rate (mm/hr)	Impervious Area (%)
E B Mahoning Creek	6	0.75	3.0
Stump Creek	6	0.90	3.0
Mahoning Creek Local	6	0.84	5.0

Table 6. Final Clark unit hydrograph parameters

Subbasin	Time of Concentration (hr)	Storage Coefficient (hr)
E B Mahoning Creek	3.7	5.9
Stump Creek	5.3	8.5
Mahoning Creek Local	9.0	14.4

8. Create an uncertainty analysis and evaluate results

The Uncertainty Analysis compute option can be used to evaluate uncertainty in model parameters on the computed results. The uncertainty analysis compute option allows the user to enter uncertainty distributions for basin model parameters, and then define the number of samples to perform. The uncertainty analysis does not vary the boundary conditions, only the selected basin model parameters. In this workshop, we will only explore the uncertainty in the loss rate parameters. Once the simulation is complete, we will review the range of output results available from the uncertainty analysis.

- 8.1. Create an uncertainty analysis. From the *Compute* menu select *Uncertainty Analysis Manager*. Name the analysis April 1994. Select *Basin Model “MahoningatPunx”* and the *Meteorologic Model “GageWeights”*.**
- 8.2. On the *Compute* tab in the *Watershed Explorer*, browse to and select the new *Uncertainty Analysis*. Finish entering the configuration information with the following time specification data. See Figure 23.**

Start Date: 10Apr1994

Start Time: 00:00

End Date: 15Apr1994

End Time: 00:00

Time Interval: 1 Hour

Total Samples: 100

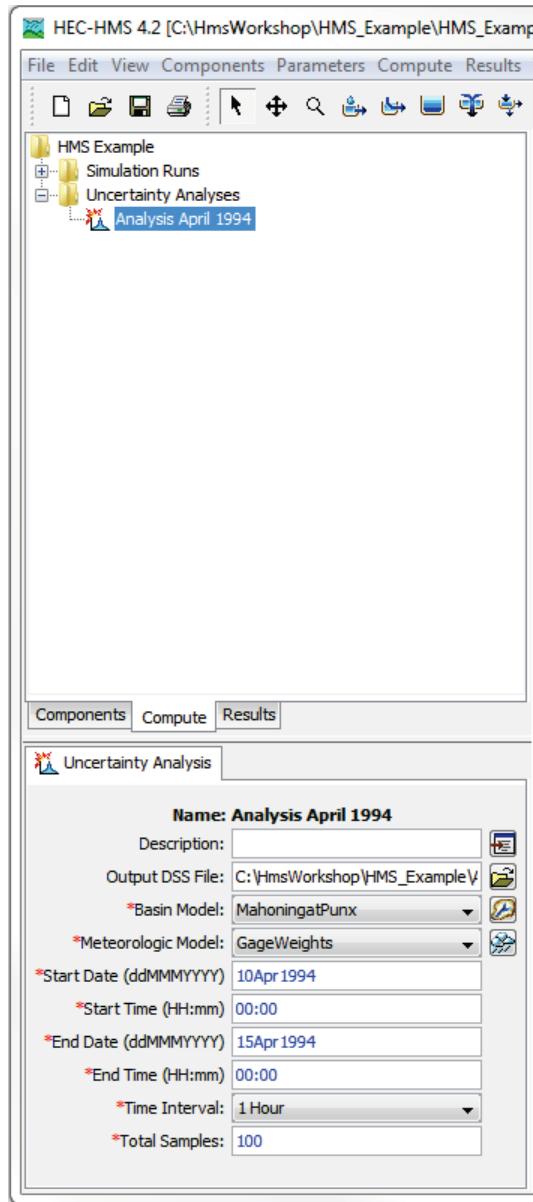


Figure 23. Completed Uncertainty Analysis Component Editor

- 8.3. Next you will add parameters to the *Uncertainty Analysis*. Right-click on the **Uncertainty Analysis** and select **Add Parameter**. Next, under the **Uncertainty Analysis**, select “Parameter 1” to edit the parameter in the **Component Editor**. In the **Component Editor** select **Element: “E B Mahoning Creek”** and **Parameter: “Initial and Constant – Constant Rate,”** as shown in Figure 24. Select a **Triangular distribution**, and enter a minimum value of **0 . 5 mm/hr**, and a maximum value of **4 . 5 mm/hr**. Distribution parameters should be **0 . 5 mm/hr** for the lower, **2 . 5 mm/hr** for the mode, and **4 . 5 mm/hr** for the upper.

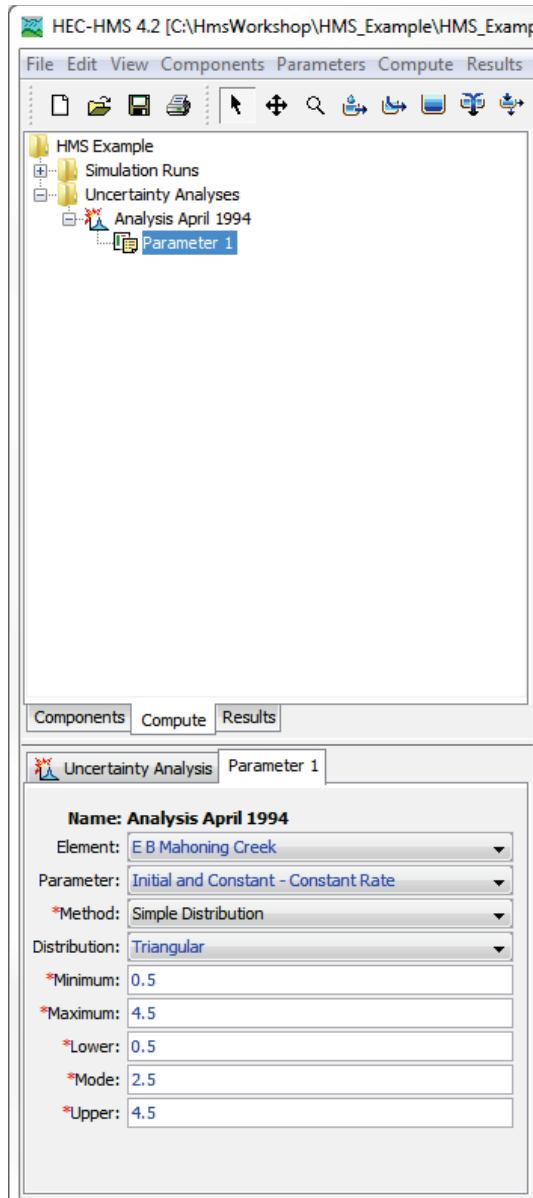


Figure 24. Configuring the first uncertainty parameter.

- 8.4. Add two additional parameters to the **Uncertainty Analysis** (Right-click “**Analysis April 1994**” and select **Add Parameter**). In the **Component Editor** set the uncertainty parameters to **Constant Rate** for the subbasins “**Stump Creek**” and “**Mahoning Creek Local**.” These two locations will be linked to the subbasin “**E B Mahoning Creek**” so that constant loss rates are adjusted in a similar manner; all values increase or decrease within a sample. In the **Component Editor**, set the sampling **Method** to **Regression With Additive Error**. Then set the **Regression Element** to “**E B Mahoning Creek**,” and set the **Regression Parameter** to **Initial and Constant – Constant Rate**. A simple linear regression can be defined where the slope is 1 and the

intercept is 0; effectively setting the parameter value to be equal to the related parameter value. The error term is represented by an uncertainty distribution. **As shown in Figure 25, select the *Normal* uncertainty distribution and enter a mean of 0 mm/hr, and a standard deviation of 0.2 mm/hr (do this for both subbasins *Stump Creek* and *Mahoning Creek Local*). These parameter values should result in constant loss rate parameters that are within 0.2 mm/hr for about 68 percent of the sampled values.**

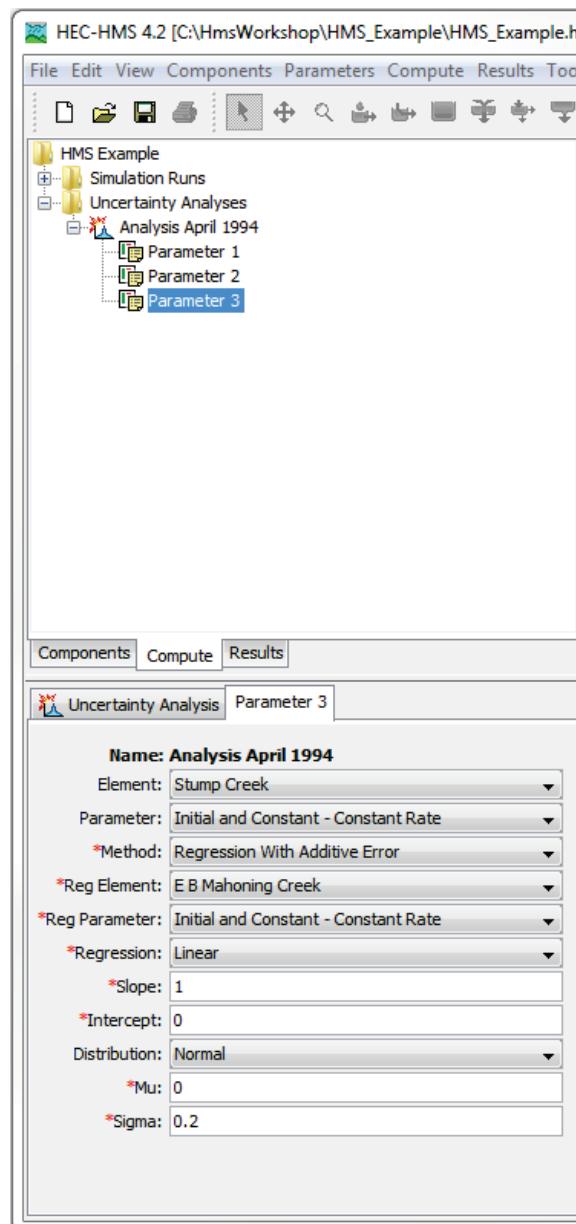


Figure 25. Configuring the Stump Creek constant loss rate parameter distribution

When complete, there should be 3 parameters selected in the uncertainty analysis.

- 8.5. The final step to preparing the *Uncertainty Analysis* for simulation is to configure the output results. In the **Watershed Explorer** to right-click on the **Uncertainty Analysis “Analysis April 1994”** and select **Results....** Next, press **Select....** Select the element **“Punxsutawney”** and time-series **Outflow** as shown in Figure 26. Close all of the results configuration windows.

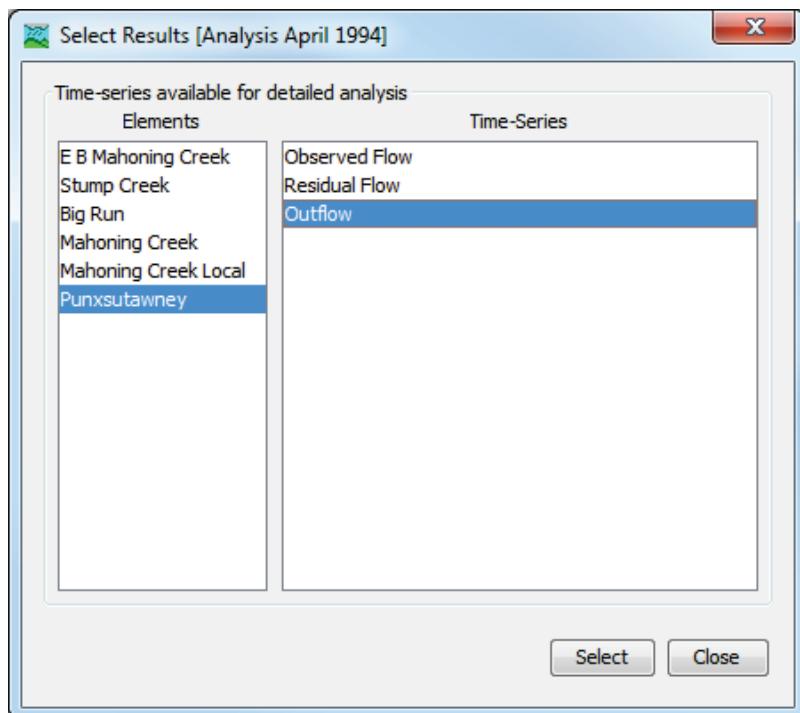


Figure 26. Choosing the Outflow time-series for the Punxsutawney element.

- 8.6. Compute the *Uncertainty Analysis* - in the **Watershed Explorer** right-click **“Analysis April 1994”** and select **Compute**. You will notice the compute dialog and message window shows progress for the 100 sample simulation. After the simulation is completed, switch to the **Results** tab of the **Watershed Explorer** and review the available results. You should see three *Parameter* tables that show the samples of constant loss rate values for each subbasin element. Figure 27 shows the sampled constant loss rate values for the “E B Mahoning Creek” subbasin. The sampled values can be copied to another program to create a histogram of values as shown in Figure 28.

Parameter Sampling Results for Uncertainty Analysis "Analysis April 1994"	
Project:HMS Example	Uncertainty Analysis:Analysis April 1994
Element:E B Mahoning Creek	Parameter:Initial and Constant - Constant Rate
Start of Analysis: 10Apr1994, 00:00	Basin Model: MahoningatPunx
End of Analysis: 15Apr1994, 00:00	Meteorologic Model:GageWeights
Compute Time: DATA CHANGED, RECOMPUTE	
Sample Number	Parameter Value
1	2.4441
2	1.3793
3	2.7554
4	2.4532
5	1.3635
6	1.5730
7	2.4388
8	2.7009
9	1.4041
10	3.6719
11	3.3468
12	2.8479
13	3.3235
14	0.89988
15	2.8115
16	2.6783
17	1.7935
18	2.0918

Figure 27. Sampled constant loss rate values for the subbasin "E B Mahoning Creek"

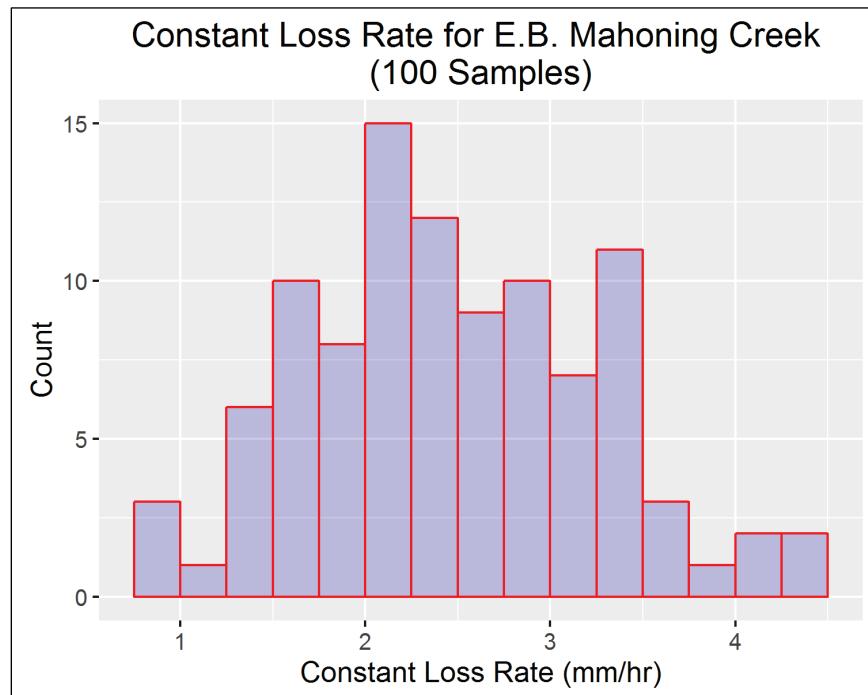


Figure 28. Histogram of constant loss rate values

There is a node for *Outflow* results at the junction "Punxsutawney." Results include hydrographs (Figure 29), and tables of the *Maximum Outflow* and *Outflow Volume*. Open the tables to view results.

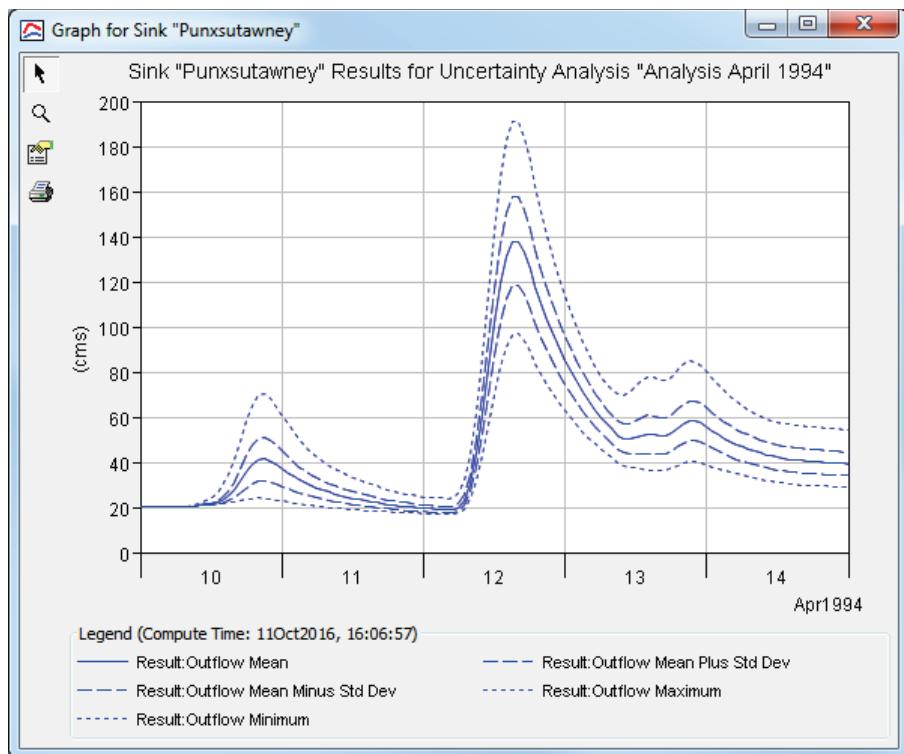


Figure 29. Hydrograph results for the Punxsutawney junction element

Assuming that the uncertainty distributions for the constant loss rate parameters reflect realistic values, the results from the uncertainty analysis illustrate that more effort should go into developing the boundary conditions for the April 1994 simulation. The mean hydrograph from 100 samples shows a peak flow that is significantly lower than the observed peak flow of 180.3 cms.